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**Liang**

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(54) **INTEGRATED CIRCUIT PACKAGE  
INCLUDING IN-SITU FORMED CAVITY**

(71) Applicant: **SKYWORKS SOLUTIONS, INC.**,  
Woburn, MA (US)

(72) Inventor: **Steve X. Liang**, San Diego, CA (US)

(73) Assignee: **SKYWORKS SOLUTIONS, INC.**,  
Woburn, MA (US)

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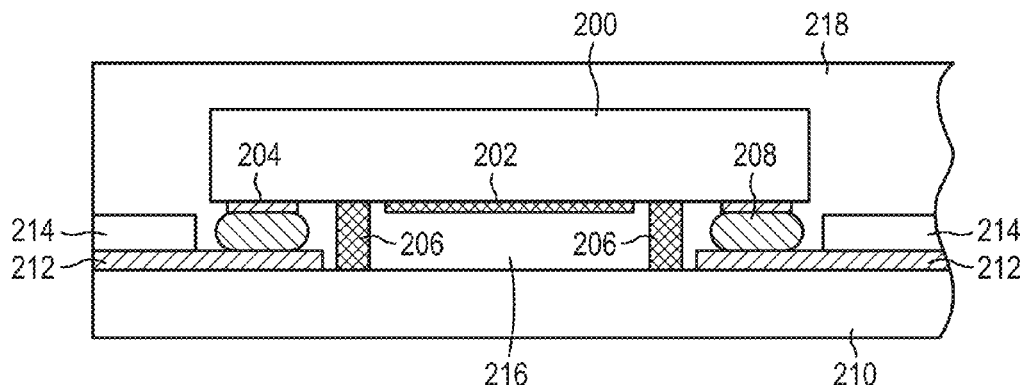
*Primary Examiner* — Edward Wojciechowicz

(74) *Attorney, Agent, or Firm* — Lando & Anastasi, LLP

(57) **ABSTRACT**

A flip chip packaged component includes a die having a first surface and a dielectric barrier disposed on the first surface of the die. The dielectric barrier at least partially surrounds a designated location on the first surface of the die. A plurality of bumps is disposed on the first surface of the die on an opposite side of the dielectric barrier from the designated location. The flip chip packaged component further includes a substrate having a plurality of bonding pads on a second surface thereof. A cavity is defined by the first surface of the die, the dielectric barrier, and the substrate. A molding compound encapsulates the die and at least a portion of the substrate.

**20 Claims, 6 Drawing Sheets**



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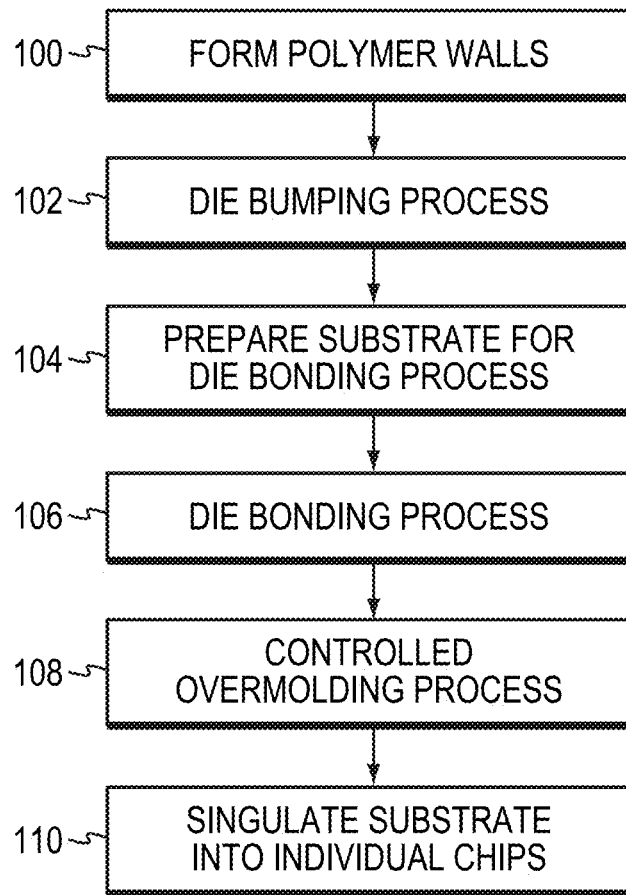


FIG. 1

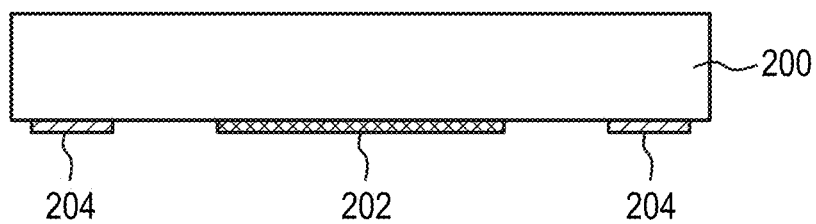


FIG. 2  
(PRIOR ART)

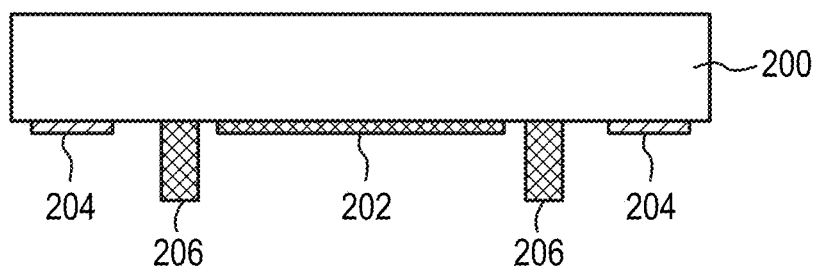


FIG. 3

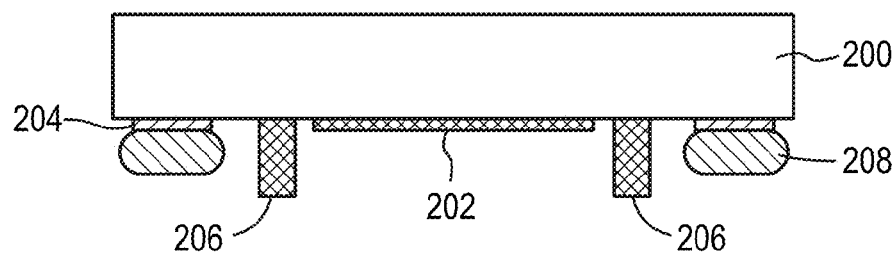


FIG. 4

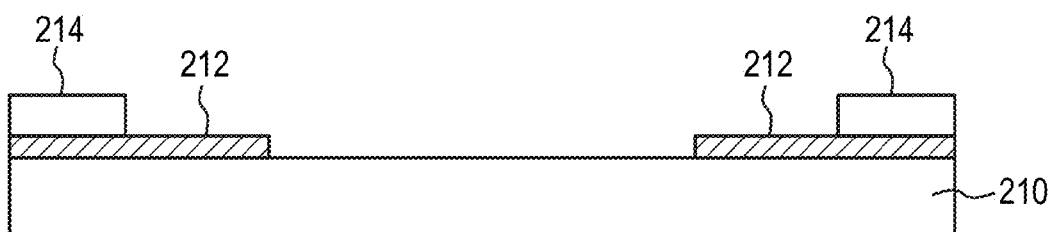


FIG. 5  
(PRIOR ART)

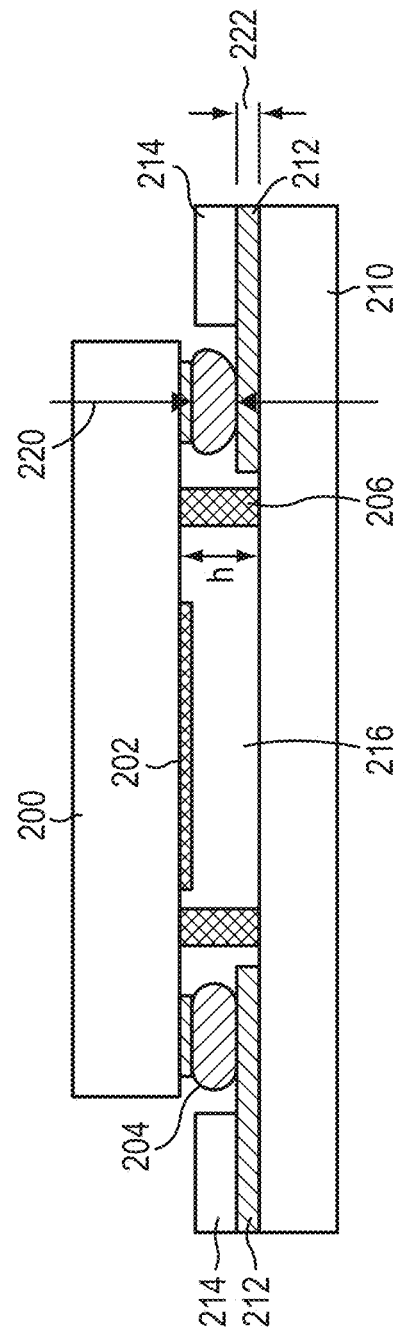


FIG. 6

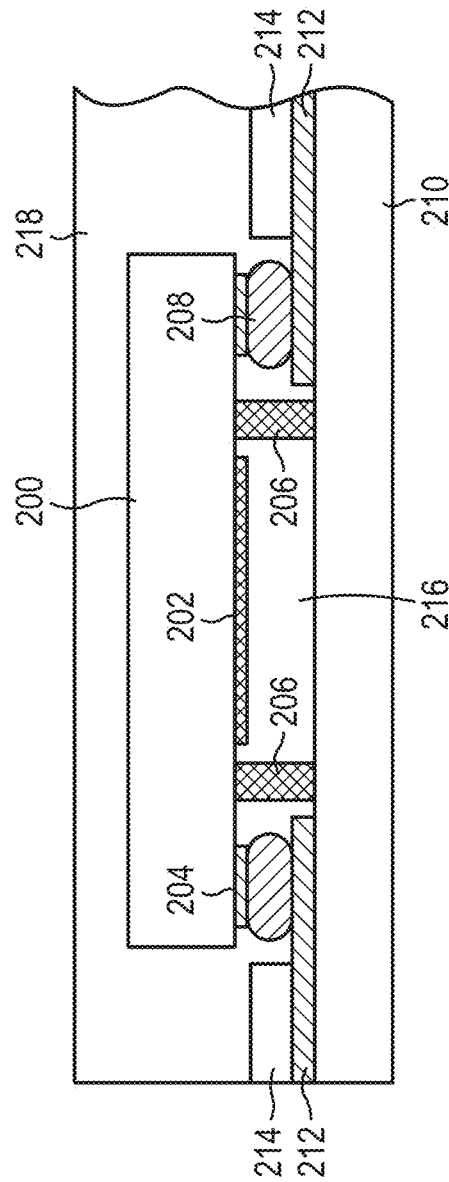


FIG. 7

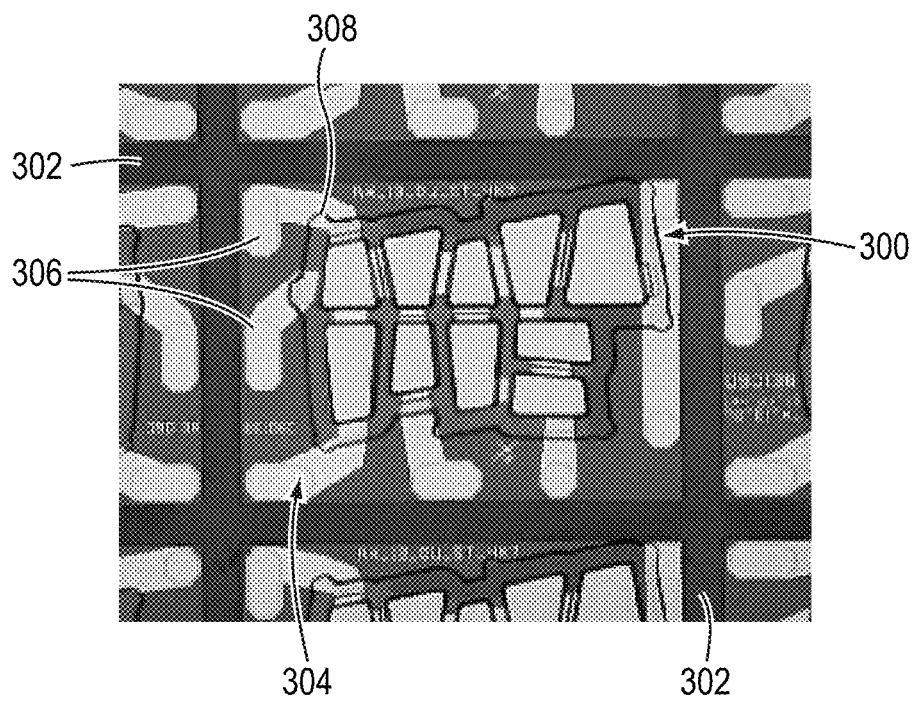


FIG. 8

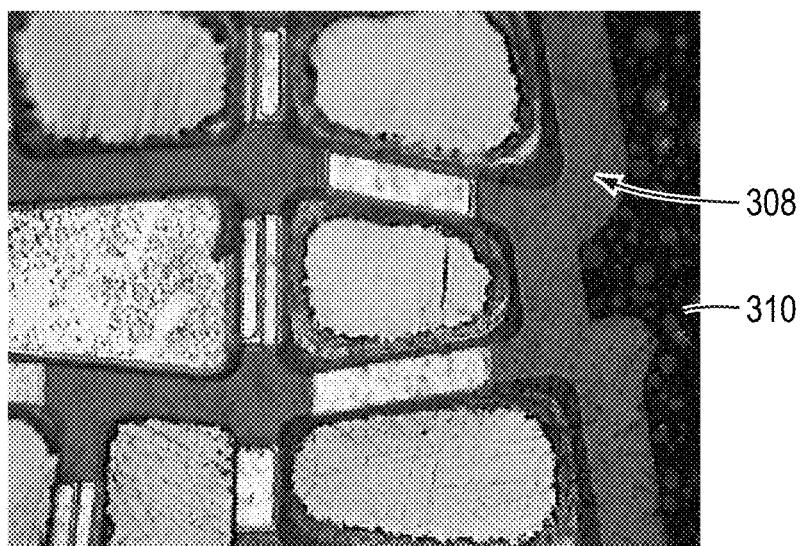


FIG. 9



1

## INTEGRATED CIRCUIT PACKAGE INCLUDING IN-SITU FORMED CAVITY

### RELATED APPLICATIONS

This application claims the benefit under 35 U.S.C. §121 as a division of U.S. application Ser. No. 11/964,092, titled "IN-SITU CAVITY INTEGRATED CIRCUIT PACKAGE," filed on Dec. 26, 2007 which is incorporated herein by reference in its entirety for all purposes.

### BACKGROUND

#### 1. Field of Invention

The present invention relates generally to semiconductor devices and methods for fabricating the same. More particularly, at least some embodiments are directed to flip chip semiconductor packages, and packaging processes, that incorporate under-die cavities.

#### 2. Discussion of Related Art

Radio frequency integrated circuits (RFICs) are widely used in wireless devices, such as cellular telephones. RFICs combine transmission lines, matching networks, and discrete components, such as inductors, resistors, capacitors and transistors, on a substrate to provide a subsystem capable of transmitting and receiving high frequency signals, for example, in a range of about 0.1 to 100 Gigahertz (GHz). Packaging of RFICs is distinctly different from packaging of digital ICs due to the fact that the package is often part of the RF circuit, and because the complex RF electrical and/or magnetic fields of the RFIC can interact with any nearby insulators and conductors. To meet growing demands in the wireless industry, RFIC packaging development seeks to provide smaller, lower cost, higher performance devices that can accommodate multi-die RF modules while providing high reliability and using lead-free solder and other "green" materials. The single chip package, in which single- or multi-die RFICs are individually packaged, is a direct solution to the small size and low cost requirements of RFICs, and is currently used for most RFICs.

Micro electromechanical systems (MEMS) enable controlled conversions between micro-scale mechanical motion and specified electrical signals, for example, with specified frequencies. MEMS are becoming widely used in RFICs. Based on mechanical movements, RF MEMS can achieve excellent signal quality factors for RF band filters, including surface acoustic wave (SAW) filters, bulk acoustic wave (BAW) filters, and high frequency RF switches. SAW filters, for example, convert electrical signals into a mechanical wave that is delayed as it propagates across a piezoelectric crystal substrate before being converted back into an electrical signal. BAW filters use volume bulk movement to achieve a specific desired resonance, and in RF switches, electrical signals are used to control movement of a micro-electrode to turn the switch ON or OFF. Current MEMS technologies have evolved from semiconductor fabrication processing. However, the mechanical motion uniquely associated with MEMS demands very different packaging constructions and requirements from conventional semiconductor ICs. In particular, inside all MEMS ICs, some materials must move freely, without interference, and therefore, MEMS ICs must be "capped" to form a small vacuum or air cavity around the moving materials to protect them while permitting their movements.

One example of a package for an RF MEMS device, developed by Infineon Technologies, AG, uses a complex passivation structure to create an air cavity underneath a SAW/BAW filter die. A photolithographic polymer is used to generate a

2

maze structure forming a cavity for each resonator. Reverse wire bonds are used to make the interconnections between the filter die and substrate. A silicon lid, e.g., a generally flat silicon wafer, with B-stage adhesive is attached on top of the maze structure to "cap" the ICs and complete the enclosed cavities. This package has been a relatively effective MEMS package as it uses standard die attach and wirebonding assembly technologies. However, it limits package size reduction, and the additional process steps of maze patterning and lid attachment add considerable complexity and cost to the package which reduces package efficiency and increases cost.

### SUMMARY OF INVENTION

At least some aspects and embodiments are directed to a semiconductor package and packaging process that provide the under-die cavities required by MEMS devices without the complexity of conventional assembly and packaging processes. In one embodiment, a thermosonic die bonding process is used in a flip chip packaging process to bond a die to a carrier substrate, as discussed further below. The die and/or the substrate are provided with dielectric walls that, once the die is bonded to the substrate, form a barrier around a designated location, preventing molding compound from flowing into the designated location. In this manner, a cavity, or air gap, can be formed beneath a selected portion of the die, for example, beneath a MEMS device. According to at least one embodiment, cavity formation is performed in situ, occurring during the die bonding process, and does not require additional steps of complex patterning or lid-attachment, as are required by conventional packaging processes.

According to one embodiment, a method of flip chip semiconductor component packaging comprises providing a die having a first surface, forming a barrier on first surface of the die, the barrier at least partially surrounding a designated location on the first surface of the die, bonding the die to a substrate in a flip chip configuration, and flowing molding compound over the die and over at least a portion of the substrate. Bonding the die to the substrate includes causing contact between the barrier and the substrate, and flow of the molding compound is blocked by the barrier to provide a cavity between the die and the substrate, the cavity being proximate the designated location on the first surface of the die.

In one example, the method further comprises an act of bumping the die. Bumping the die may include forming gold bumps or copper pillar bumps on the first surface of the die. For gold bumps, bonding the die to the substrate may be achieved using a gold-to-gold interconnect process to form bonds between the gold bumps on the die and gold-plated conductive pads on the substrate. For copper pillar bumps, bonding the die to the substrate may include using a thermosonic bonding process to form bonds between the copper pillar bumps on the die and conductive bonding pads on the substrate. Forming the barrier may include forming a dielectric barrier such as, for example, a barrier comprising SU8 polymer.

According to another embodiment, a flip chip packaged component comprises a substrate having a first surface, the substrate comprising a plurality of conductive pads disposed on the first surface, a die having a second surface, the die comprising a plurality of bumps disposed on the second surface, each bump of the plurality of bumps being bonded to a respective one of the conductive pads, a dielectric barrier coupled between the substrate and the die, and disposed at least partially surrounding a designated location on the die to

define a cavity between the die and the substrate, and molding compound covering the die and at least a portion of the die, wherein the molding compound is absent from the cavity.

The plurality of bumps may comprise, for example, a plurality of copper pillar bumps or a plurality of gold bumps. In one example, the die comprises a circuit disposed within the designated location. This die may comprise a MEMS device disposed within the designated location. In another example, the cavity is a resonant cavity. The dielectric barrier may comprise SU8 polymer. In one example, there is zero gap between the barrier and the substrate and between the barrier and the die. In another example, the barrier completely surrounds the designated location on the second surface of the die.

Another embodiment is directed to a method of flip chip semiconductor component packaging comprising providing a die having a plurality of connection bumps formed on a first surface thereof, providing a substrate having a corresponding plurality of conductive bonding pads formed on a second surface thereof, forming a dielectric barrier on the first surface of the die, the dielectric barrier at least partially surrounding a designated location on the first surface of the die, thermosonically bonding the die to the substrate, and compressing the dielectric barrier during the bonding to eliminate any gap between the barrier and the substrate and form a cavity between the die and the substrate, the cavity being defined by the barrier. Thermosonically bonding the die to the substrate may include using a gold-to-gold interconnect process to bond the plurality of connection bumps to the corresponding plurality of conductive bonding pads. Providing the die may include providing a die comprising a MEMS device, the MEMS device being at least partially disposed within the designated location on the die. In one example, forming the dielectric barrier includes forming a dielectric barrier that completely surrounds the designated location on the first surface of the die. In another example, the method further comprises an act of flowing molding compound over the die and over at least a portion of the substrate, wherein flow of the molding compound is blocked by the barrier which prevents the molding compound from entering the cavity. Forming the dielectric barrier may comprise forming a barrier made of SU8 polymer.

According to another embodiment, a method of flip chip semiconductor component packaging comprises providing a die having a plurality of connection bumps formed on a first surface thereof, providing a substrate having a corresponding plurality of conductive bonding pads formed on a second surface thereof, forming a dielectric barrier on the second surface of the substrate, thermosonically bonding the die to the substrate, and compressing the dielectric barrier during the bonding to eliminate any gap between the barrier and the die and form a cavity between the die and the substrate, the cavity being defined by the barrier. In one example, forming the dielectric barrier includes forming a barrier made of SU8 polymer. Thermosonically bonding the die to the substrate may include using a gold-to-gold interconnect process to bond the plurality of connection bumps to the corresponding plurality of conductive bonding pads. In one example, providing the die includes providing a die comprising a MEMS device, the MEMS device being at least partially disposed within the designated location on the die. In another example, forming the dielectric barrier includes forming a dielectric barrier that completely surrounds the designated location on the first surface of the die. The method may further comprise flowing molding compound over the die and over at least a portion of the substrate; wherein flow of the molding com-

pound is blocked by the barrier which prevents the molding compound from entering the cavity.

Still other aspects, embodiments, and advantages of these exemplary aspects and embodiments, are discussed in detail below. Moreover, it is to be understood that both the foregoing information and the following detailed description are merely illustrative examples of various aspects and embodiments, and are intended to provide an overview or framework for understanding the nature and character of the claimed aspects and embodiments. The accompanying drawings are included to provide illustration and a further understanding of the various aspects and embodiments, and are incorporated in and constitute a part of this specification. The drawings, together with the remainder of the specification, serve to explain principles and operations of the described and claimed aspects and embodiments.

#### BRIEF DESCRIPTION OF THE DRAWINGS

Various aspects of at least one embodiment are discussed below with reference to the accompanying figures. In the figures, which are not intended to be drawn to scale, each identical or nearly identical component that is illustrated in various figures is represented by a like numeral. For purposes of clarity, not every component may be labeled in every drawing. The figures are provided for the purposes of illustration and explanation and are not intended as a definition of the limits of the invention. In the figures:

FIG. 1 is a flow diagram illustrating one example of a packaging process according to aspects of the invention;

FIG. 2 is a cross-sectional diagram of one example of an RFIC die;

FIG. 3 is a cross-sectional diagram of a die comprising dielectric walls according to aspects of the invention;

FIG. 4 is a cross-sectional diagram of the die of FIG. 3 after bumping;

FIG. 5 is a cross-sectional diagram of one example of a conventional plated substrate;

FIG. 6 is a cross-sectional diagram of the die of FIG. 4 bonded to the plated substrate of FIG. 5, according to aspects of the invention;

FIG. 7 is a cross-sectional diagram of a packaged device according to aspects of the invention;

FIG. 8 is an image of a portion of a semiconductor substrate having a BAW filter formed thereon, according to aspects of the invention; and

FIG. 9 is an enlarged image of a portion of the BAW filter of FIG. 8, illustrating the dielectric walls blocking molding compound from entering the cavity.

#### DETAILED DESCRIPTION

One semiconductor packaging technique that is widely used for radio frequency integrated circuits (RFICs) is referred to as “flip chip” packaging, in which the interconnection between a die (that comprises the RF circuit) and a substrate (that provides structure support) is made through a conductive “bump” placed directly on the surface of the die. The bumped die is then “flipped over” and placed face down on the substrate, with the bumps connecting the die directly to the substrate. As discussed above, flip chip RFICs, particularly those comprising MEMS devices require (or greatly benefit from) a cavity disposed between the MEMS circuit and the substrate. However, conventional techniques for providing these cavities have required complex assembly procedures, including attachment of a flat “lid” wafer to complete the cavity. By contrast, at least some aspects and embodiments

are directed to a flip chip packaging method that incorporates in situ formation of cavities underneath selected portions of the die during the flip chip die bonding process.

In situ creation of cavities (e.g., air gaps) underneath dies may be accomplished through selective patterning of conductive (e.g., copper) and dielectric (e.g., solder mask and polymer) materials on the die and/or substrate and the use of a controlled overmolding process. As discussed below, according to at least one embodiment, a wall of dielectric may be provided on the die or substrate to form a barrier around a designated location when the die is bonded to the substrate. Substantially zero gap is allowed between the wall and the die/substrate, such that the wall prevents the flow of molding compound into the designated location during the overmolding process. Embodiments of the invention provide advantages of reducing or eliminating the additional process steps such as lid attachment, cap wafer bonding, etc. that are required by conventional cavity formation techniques. Thus, embodiments of the invention may facilitate simple assembly process flow and low cost packaging of RFICs, such as BAW or SAW filters, or other MEMS devices. In addition, as discussed below, a thermosonic die bonding process may be used in conjunction with a low cost gold stud or copper-pillar bumping technique, further facilitating low cost packaging as well as fluxless bonding to minimize contamination.

It is to be appreciated that embodiments of the methods and apparatuses discussed herein are not limited in application to the details of construction and the arrangement of components set forth in the following description or illustrated in the accompanying drawings. The methods and apparatuses are capable of implementation in other embodiments and of being practiced or of being carried out in various ways. Examples of specific implementations are provided herein for illustrative purposes only and are not intended to be limiting. In particular, acts, elements and features discussed in connection with any one or more embodiments are not intended to be excluded from a similar role in any other embodiments. Also, the phraseology and terminology used herein is for the purpose of description and should not be regarded as limiting. The use herein of “including,” “comprising,” “having,” “containing,” “involving,” and variations thereof is meant to encompass the items listed thereafter and equivalents thereof as well as additional items.

A flow diagram of one example of a method of packaging semiconductor devices is illustrated in FIG. 1. Aspects and embodiments of the packaging method are discussed below with continuing reference to FIG. 1.

Referring to FIG. 2, there is illustrated a cross-sectional view of one example of a die 200. The die 200 may be an RFIC, and in at least one example, includes a Micro electro-mechanical systems (MEMS) device, designated by circuit 202. However, the invention is not limited to MEMS devices, and the circuit 202 may comprise a circuit other than an RF circuit and other than a MEMS device. The die 200 also comprises bonding pads 204 to which bumps can be attached to allow the die 200 to be mounted flip chip to a substrate, as discussed further below.

According to one embodiment, a step 100 in the packaging method includes forming a barrier around a designated location on the die 200, for example, around the circuit 202. This barrier will provide a cavity in proximity to the circuit 202 after the die 200 is bonded to a substrate, as discussed further below. The barrier is provided by forming walls 206 on the die surrounding, or at least partially surrounding the circuit 202. In one example, these walls 206 are formed of a polymer, such as SUB. The step 100 may comprise depositing a layer of polymer on the die and selectively removing the polymer so

as to form the walls 206. Alternatively, the polymer may be selectively deposited to directly form the walls 206. Polymer deposition (and selective removal) has the advantage of being a simple manufacturing method that can be accomplished using known fabrication techniques. However, the invention is not limited to the use of polymer to form the walls 206 and other materials, such as dielectrics other than polymers, may be used instead.

As discussed above, in flip chip packaging, the die is directly bonded to a substrate via “bumps” disposed on the die. Therefore, referring again to FIG. 1, a step 102 includes a die bumping process to prepare the die 200 for bonding. A die 200 comprising bumps 208 is illustrated in FIG. 4. There are several types of bumps and bumping processes that are used for flip chip devices. One example includes forming gold bumps 208 on the die 200 by creating stud shape bumps with standard wire bonding gold wire. In another example, gold bumps may be formed by depositing a layer of gold in the desired bump locations, or by gold-plating a bonding pad 204 formed of another material (e.g., nickel). Gold bumps are favored in many applications because gold bonds have good bond strength, excellent high frequency performance and low resistance. In another example, the bumping process 102 may include forming copper pillar bumps 208 on the die 200. Copper pillar bumps comprise a copper pillar attached to the bond pad 204 and a bonding cap (not shown) disposed on top of the copper pillar. Copper pillar bumps offer advantages such as excellent electrical connections with improved thermal characteristics due to the good conductivity of copper. In addition, a copper pillar bump can be narrower than a spherical solder bump of the same height, due to the copper cylinder, and may thus facilitate a finer connection grid. To manufacture copper pillar bumps, the bumping step 100 may comprise a two stage electroplating process in which the copper pillar is electroplated onto the pad 204, and the bonding cap (which may typically comprise solder or gold) is deposited on top of the copper cylinder.

It is to be appreciated that although step 100 of forming the barrier 206 is illustrated in FIG. 1 as preceding the die bumping process 102, the invention is not so limited, and the order in which these steps are performed may be reversed. In addition, either or both steps 100 and 102 may be performed at the individual die level or at a wafer level. For example, a wafer may comprise a plurality of dies, typically many hundreds or thousands of dies. After bumping and/or formation of the barriers, the wafer may be singulated into the individual dies 200.

Still referring to FIG. 1, in one embodiment, the packaging process includes a step 104 of preparing a substrate for the die bonding process 106. Referring to FIG. 5, there is illustrated an example of a substrate. The substrate 210 comprises conductive pads 212 to which the bumps of the die may be attached. A common substrate material is a printed circuit board made with organic resin. However, the substrate 210 may alternatively comprise ceramic, silicon or another insulative material. In one example, the substrate is a laminate substrate, such as FR4, with gold finishing, such that the pads 212 are formed of gold (or at least are gold-plated). Alternatively, in other examples, the pads may comprise a conductive material or metal other than gold, such as, for example, copper, silver, palladium, or solder. Prior to bonding the dies, the conductive pads 212 may be cleaned (as part of step 104), for example, using a plasma cleaning process, as known to those skilled in the art. The preparing step 104 may also include depositing a dielectric layer (such as a solder mask) 214. It is to be appreciated that although step 104 is illustrated in FIG.

1 as following steps **100** and **102**, the invention is not so limited and step **104** may be performed at any time prior to bonding (i.e., step **106**).

Referring again to FIG. 1, step **106** includes bonding one or more dies **200** to the substrate **210**. According to one embodiment, the die bonding process **106** includes a thermosonic process in which thermal energy and mechanical pressure are applied to the die **200** to form a bond between the pads **212** on the substrate **210** and the bumps **208**. As discussed above, in one example, the bumps **208** can be gold bumps. In this case, a standard gold-to-gold interconnect (GGI) bonding process can be used. GGI is a thermosonic process by which gold bumps and gold bond pads are joined together by heat and ultrasonic power under a pressure head, using a machine called a GGI bonder. The thermosonic process connection is made by solid-phase bonding between the two gold layers. Diffusion of gold (micro-welding) under load, and ultrasonic power, creates the gold-to-gold connection as a bond layer that is void-free and monolithic. GGI bonding is a relatively low cost technology, and is also a fluxless bonding method, which is environmentally friendly and minimizes contamination of the devices. The ultrasonic GGI process has a mounting accuracy of about  $\pm 10\text{ }\mu\text{m}$  and can reliably bond dies with a thickness as thin as  $100\text{ }\mu\text{m}$ . In another example, the bumps **208** may be copper pillar bumps as discussed above, and a thermosonic process may be used to bond the die **200** to the substrate **210**. An example of a thermosonic bonding process that may be used is described in commonly-owned and co-pending U.S. patent application Ser. No. 11/957,730 filed Dec. 17, 2007, entitled "Thermal Mechanical Flip Chip Bonding," which is herein incorporated by reference in its entirety.

Referring to FIG. 6, there is illustrated a cross-sectional view diagram of the die **200** bonded to the substrate **210**. In one embodiment, the height,  $h$ , of the walls **206** is controlled such that when the die **200** is bonded to the substrate **210**, the walls **206** are slightly compressed so as to leave essentially zero gap between the walls **206** and the substrate **210**. The walls **206** thus form a barrier around the circuit **202** and form a cavity **216** beneath the die. This cavity (or air gap) **216** is formed in situ during the die bonding process **106**, without requiring a separate "cap" to be attached to complete the cavity, as is the case with conventional cavity-forming methods. Although only left and right walls are depicted in FIG. 7, it should be appreciated that additional walls (e.g., front and back in FIG. 7) may be provided to partially or completely surround the circuit **202**. It should further be appreciated that the walls may have any desired shape dictated only by the requirements of the application for which the circuit is intended. When a molding compound **218** (see FIG. 7) is applied over the die **200** and substrate **210** in a controlled overmolding process (step **108**), the walls **206** prevent the molding compound **218** from entering the cavity **216**, and thus maintain the cavity **216** beneath the circuit **202**. It is to be appreciated that although the cavity may most commonly be filled with air, it may also be filled with another substance or a vacuum.

According to one example, the height of the walls **206** is selected based at least in part on the material that the walls **206** are made of (i.e., a compressibility of the walls), a known height **222** of the bonding pads **212**, a stand-off **220** of the bumps **208**, and the pressure to be exerted during thermosonic bonding of the die **200** to the substrate **210**. In one example, the height **222** of the conductive bond pads **212** is about 27 micrometers ( $\mu\text{m}$ ), and the bump stand-off **220** is in a range of about 10-20  $\mu\text{m}$ . The bump stand-off may decrease during bonding of the die **200** to the substrate **210**. Therefore, in one

example, the height,  $h$ , of the walls **206** is about  $40\text{ }\mu\text{m}$ , such that after bonding, there is essentially zero gap between the walls **206** and the substrate **210**. It is to be appreciated that the dimensions given herein are examples only, and not intended to be limiting. The dimensions of the walls **206**, conductive pad **212** and bump stand-off **220** may vary depending on the application, materials used and die bonding process used.

As discussed above, in at least some embodiments, the walls **206** are formed on the die **200** prior to bonding of the die **200** to the substrate **210**. Alternatively, however, the walls **206** may be formed on the substrate **210** prior to bonding of the die **200** to the substrate **210**. The walls **206** may be formed on the substrate **210** through controlled patterning of the substrate and using conventional dielectric deposition processes, and optional selective removal processes, as discussed above. In this example, the stand-off (i.e., height) of the walls **206** and bumps **208** can be controlled so as to provide essentially zero gap between the top of the walls and the die **200** when the die **200** is bonded to the substrate **210**.

Some examples of packaged BAW filters were produced using an embodiment of the packaging method discussed herein. A top surface image of a portion of a substrate comprising an example BAW filter **300** is illustrated in FIG. 8. The BAW filters **300** are separated from one another on the substrate by "streets" **302** that were formed using conventional methods. The BAW filter comprises several conductive connection points **304** that allow signals to be provided to and from the BAW filter **300**. The barrier **308** formed by the dielectric walls **206** (see FIG. 6) is clearly visible surrounding the BAW filter die. In this example, the barrier **308** comprises SU8 polymer. Molding compound was applied over the BAW filters using a controlled overmolding process. The barrier **308** prevents the molding compound flow at designated locations to create unfilled air gaps underneath the BAW filter dies. Blocking of the molding compound **310** by the barrier **308** can be seen in FIG. 9 which is an enlarged image of a portion of the BAW filter **300**. After the overmolding process, the substrate may be singulated, along the streets **302**, to form individual packaged components (step **110** in FIG. 1).

To test the robustness of components formed using the flip chip packaging method of embodiments of the invention, several example BAW filter components were produced and subjected to "shear" tests. In these tests, shear force is exerted upon the component, with the force being continuously (or incrementally) increased until the die is sheared off from the substrate. This test provides data regarding the strength or mechanical integrity of the bond between the bumps **208** and the die **200** and between the bumps **208** and the substrate pads **212**. Table 1 below contains test result data for eleven examples of BAW filters manufactured according to an embodiment of the packaging process discussed herein. In each of the examples, the dies comprised gold bumps **208** and were bonded to the substrates using a GGI bonding process. The GGI bonding machine was programmed to apply bond force of 5 Newtons, and to apply 1.5 Watts of ultrasonic power for 0.3 seconds during the GGI bonding process.

TABLE 1

Die shear data for examples of BAW filter packages			
Example No.	Bump transfer*	Bump height ( $\mu\text{m}$ )	Die shear force (Kgf)
1	6	20.3	261.50
2	5	21.9	331.80
3	4	19.5	227.90
4	5	20.9	202.80

TABLE 1-continued

Die shear data for examples of BAW filter packages			
Example No.	Bump transfer*	Bump height (μm)	Die shear force (Kgf)
5	5	22.0	254.60
6	5	22.5	255.40
7	4	21.8	241.40
8	6	24.3	248.20
9	4	23.8	244.00
10	6	23.4	210.20
11	6	20.8	219.40
Minimum	4.00	19.5	202.80
Maximum	6.00	24.3	331.80
Average	5.09	21.93	245.17
Standard deviation	0.83	1.5	34.60

\*"Bump transfer" refers to the number of bumps that shear off from the die under the die shear force listed in column 4, suggesting good bonding between bumps and substrate pads.

The data in Table 1 indicates that components packaged according to examples of the packaging method discussed herein demonstrate good joint strength and reliability. The presence of the in situ cavity, and lack of molding compound in the cavity area, does not adversely affect the mechanical reliability of the component. Thus, aspects and embodiments provide a robust, reliable packaged component, such as an RFIC (particularly a MEMS device), that incorporates in situ formation of an under-die cavity in a simple, clean and low cost packaging method.

Having thus described several aspects of at least one embodiment, it is to be appreciated various alterations, modifications, and improvements will readily occur to those skilled in the art. Such alterations, modifications, and improvements are intended to be part of this disclosure and are intended to be within the scope of the invention. Accordingly, the foregoing description and drawings are by way of example only, and the scope of the invention should be determined from proper construction of the appended claims, and their equivalents.

What is claimed is:

1. A flip chip packaged component comprising:  
a die having a first surface;  
a dielectric barrier disposed on the first surface of the die, the dielectric barrier at least partially surrounding a designated location on the first surface of the die;  
a plurality of bumps disposed on the first surface of the die, the plurality of bumps being located on an opposite side of the dielectric barrier from the designated location;  
a substrate including a plurality of bonding pads on a second surface of the substrate, the die bonded to the substrate in a flip chip configuration, the plurality of bumps bonded to the plurality of bonding pads, the dielectric barrier contacting the substrate;  
a cavity defined by the first surface of the die, the dielectric barrier, and the substrate, the cavity being proximate the designated location on the first surface of the die; and  
a molding compound encapsulating the die and at least a portion of the substrate, the molding compound underfilling a portion of the die and contacting the opposite side of the dielectric barrier from the designated location, the dielectric barrier preventing the molding compound from entering the cavity.
2. The component of claim 1 wherein the plurality of bumps include a conductive material.
3. The component of claim 2 wherein the plurality of bumps include gold bumps.

4. The component of claim 3 wherein the plurality of bonding pads are gold-plated bonding pads.

5. The component of claim 2 wherein the plurality of bumps include copper pillar bumps.

6. The component of claim 1 wherein the cavity is free of the molding compound.

7. The component of claim 1 wherein the dielectric barrier includes SU8 polymer.

8. A flip chip semiconductor component package comprising:

a die having a plurality of connection bumps formed on a first surface thereof;

a substrate having a corresponding plurality of conductive bonding pads formed on a second surface thereof, the plurality of connection bumps on the first surface of the die bonded to the plurality of conductive bonding pads on the second surface of the substrate;

a dielectric barrier disposed on the first surface of the die, the dielectric barrier at least partially surrounding a designated location on the first surface of the die, the designated location being free of any of the plurality of connection bumps, the dielectric barrier bonded to the substrate with a gap-free bond;

a cavity defined by the dielectric barrier between the first surface of the die and the substrate; and

a molding compound encapsulating the die and at least a portion of the substrate, the molding compound underfilling a portion of the die, the dielectric barrier preventing the molding compound from entering the cavity.

9. The package of claim 8 wherein the plurality of conductive bonding pads are gold-plated bonding pads and the plurality of connection bumps include gold bumps.

10. The package of claim 8 wherein the die includes a MEMS device.

11. The package of claim 10 wherein the MEMS device is at least partially disposed within the designated location.

12. The package of claim 8 wherein the dielectric barrier completely surrounds the designated location.

13. The package of claim 8 wherein the dielectric barrier includes SU8 polymer.

14. A flip chip semiconductor component package comprising:

a die having a plurality of connection bumps formed on a first surface thereof;

a substrate having a corresponding plurality of conductive bonding pads formed on a second surface thereof, the plurality of connection bumps on the first surface of the die bonded to the plurality of conductive bonding pads on the second surface of the substrate;

a dielectric barrier disposed on the second surface of the substrate and bonded to the die with a gap-free bond;

a cavity defined by the dielectric barrier between the first surface of the die and the substrate; and

a molding compound encapsulating the die and at least a portion of the substrate, the molding compound underfilling a portion of the die, the dielectric barrier preventing the molding compound from entering the cavity.

15. The package of claim 14 wherein the dielectric barrier includes SU8 polymer.

16. The package of claim 14 wherein the plurality of conductive bonding pads are gold-plated bonding pads and the plurality of connection bumps include gold bumps.

17. The package of claim 14 wherein the die includes a MEMS device.

18. The package of claim 14 wherein the dielectric barrier completely surrounds the cavity.

**11**

**12**

**19.** The package of claim **18** wherein the cavity is free of any of the plurality of connection bumps.

**20.** The package of claim **14** wherein the cavity is a resonant cavity.

\* \* \* \* \*

UNITED STATES PATENT AND TRADEMARK OFFICE  
**CERTIFICATE OF CORRECTION**

PATENT NO. : 9,153,551 B2  
APPLICATION NO. : 14/536068  
DATED : October 6, 2015  
INVENTOR(S) : Steve X. Liang

Page 1 of 1

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

In the Specification:

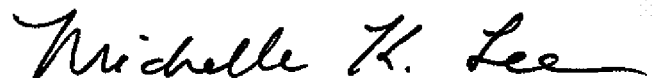
Column 2, Line 42, delete "bather" and insert -- barrier --.

Column 5, Line 59, delete "bather" and insert -- barrier --.

Column 5, Line 66, delete "SUB" and insert -- SU8 --.

Column 8, Line 30, delete "bather" and insert -- barrier --.

Signed and Sealed this  
Fifteenth Day of March, 2016



Michelle K. Lee  
*Director of the United States Patent and Trademark Office*